by
Fred
Blechman

Build Quick Henry to Measure Inductance

Build this simple adapter for use with your audio or RF signal generator and you can measure inductance values from 1 microhenry to over 1 henry. It uses an internal or external analog microammeter, or an oscilloscope, as a peak or null indicator.

Measuring the inductance of a choke, transformer, intermediate frequency (IF) can, toroid, open-air, or any other coil is a relatively clumsy process for the home experimenter or small repair shop. Unless equipped with an inductance bridge, the measurement of inductance is usually avoided because of the difficulty in making the measurement.

However using "Quick Henry" and two simple charts, anyone with an audio frequency (AF) generator can measure inductance quickly and easily from 1 millihenry (mH) to over 1 henry (H). With the use of a radio frequency (RF) generator, measurements can be made down to one microhenry (uH). Furthermore, using a calculator or simple BASIC computer program, measurements can be calculated beyond these ranges.

In addition, Quick Henry will allow you to determine the resonant frequency and sharpness of response ("Q") of audio and RF circuits from below 100 cycles per second (hertz, or Hz) to over 15 megahertz (MHz) with reasonable accuracy. The resonant frequency of unmarked IF transformers can be easily identified, and you can determine the inductance of

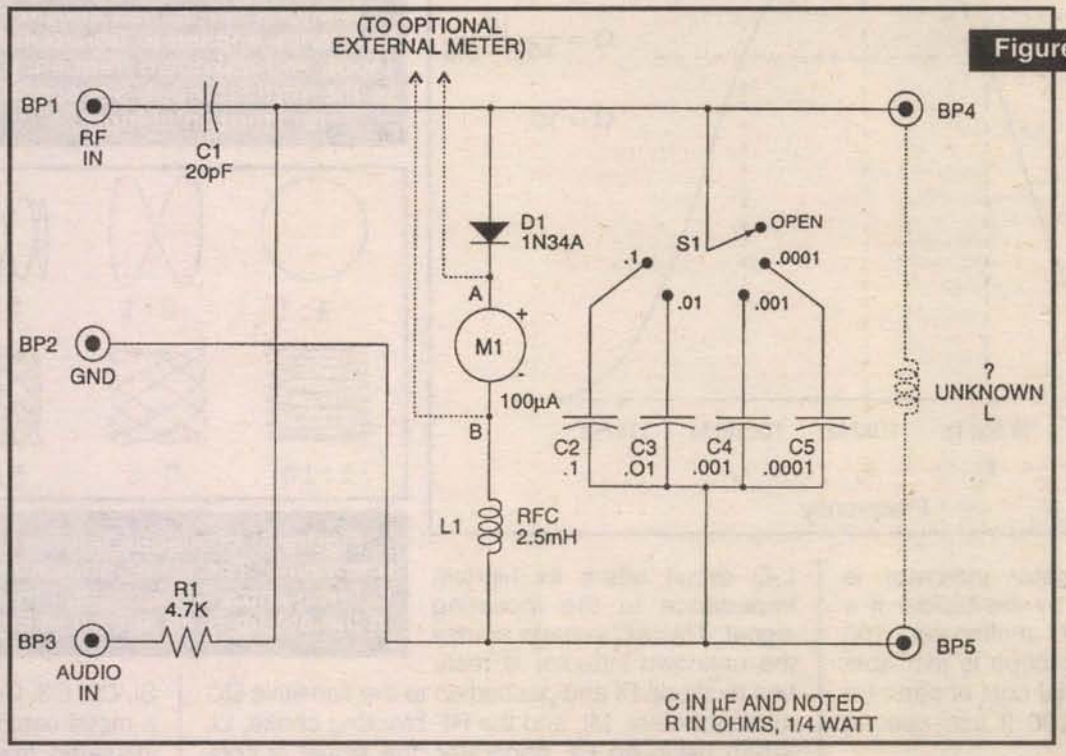


Figure 1: Quick Henry Schematic

Figure 2: Resonant Frequency vs. Inductance (Audio Range)

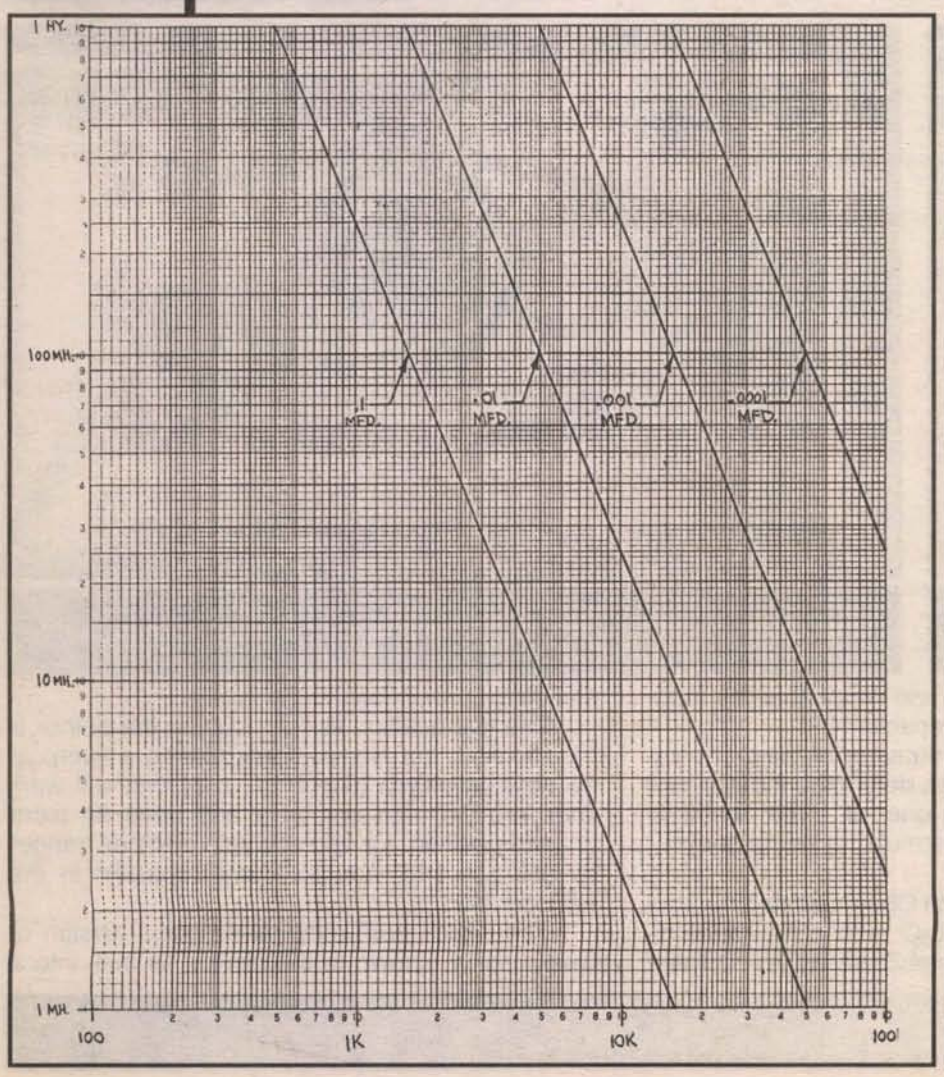
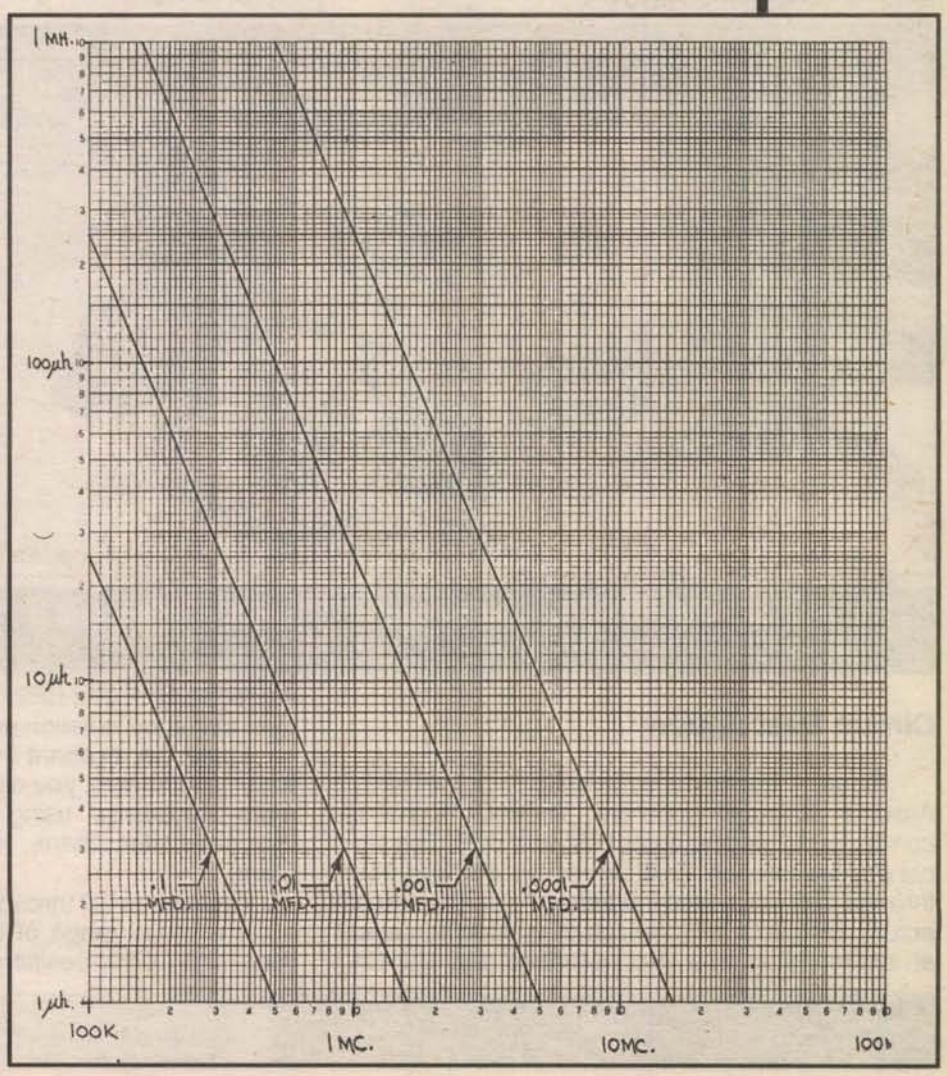
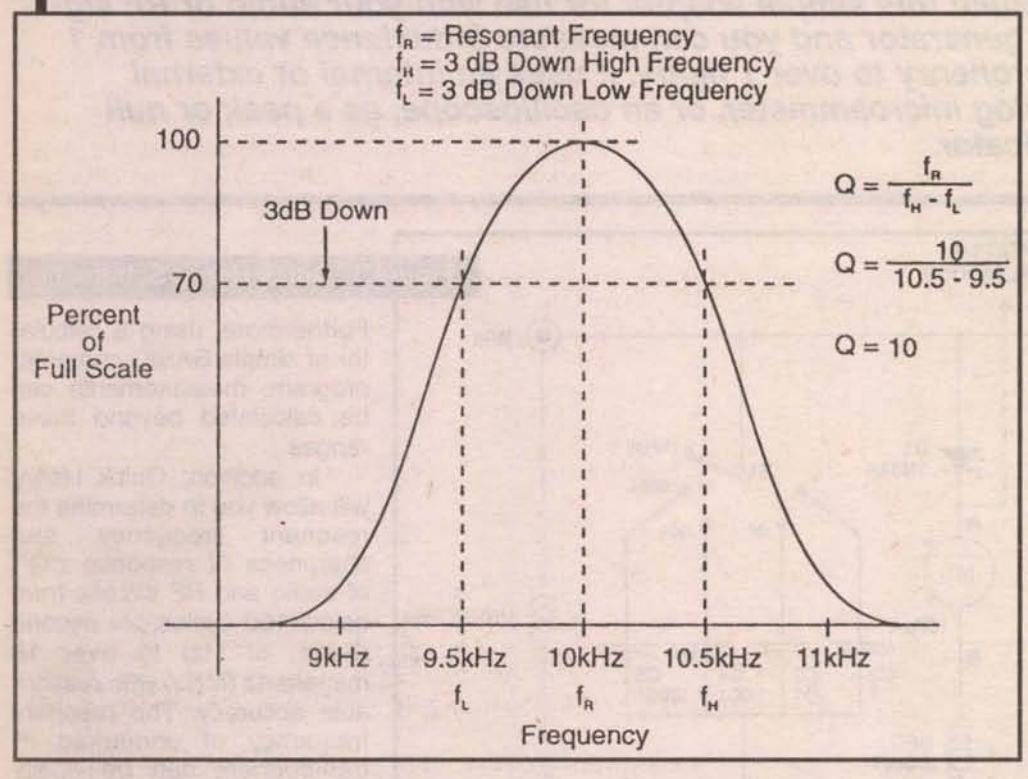


Figure 3: Resonant Frequency vs. Inductance (RF Range)



unmarked filter chokes, slug-tuned coils, RF chokes, etc. You can design, test, and trim air-wound coils and audio band pass circuits to your requirements.

Figure 4: Calculating Q with Quick Henry



Quick Henry's built-in meter indicator is optional, and may be omitted by the builder if a 10,000 ohms/volt or better DC multimeter, 100 microamp DC meter, or oscilloscope is available as an external indicator. The total cost of parts for Quick Henry is less than $10.00 if you use an external indicator.

or C5), which is placed in parallel with the unknown inductor.

The audio input frequency is varied and, as the resonant frequency of the parallel combination of the unknown L and the selected C is approached, the voltage across BP4-BP5 increases sharply. At its resonant frequency, the parallel L-C circuit offers its highest impedance to the incoming signal. This AC voltage across the unknown inductor is rectified by diode D1 and passed on to the sensitive DC microammeter, M1, and the RF-blocking choke, L1. When using an RF generator, the signal is connected to BP1 and BP2, and coupled to the resonant circuit by isolation capacitor C1.

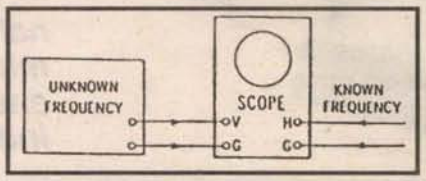


Figure 5: Typical oscilloscope Lissajous set-up has known frequency applied to horizontal input, and unknown frequency to the vertical input. Set scope for Horizontal Input.

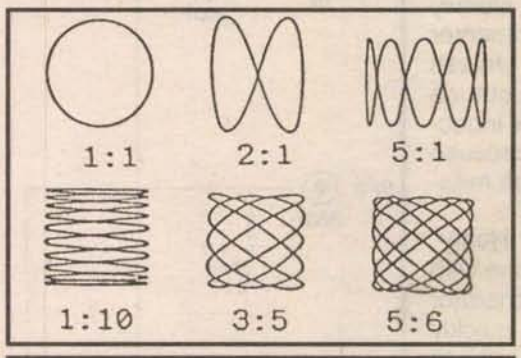


Figure 6: Lissajous figures using sinewaves. The ratios shown are vertical frequency to horizontal frequency if the set-up is as shown in Figure 5.

Once the resonant frequency of the L-C combination is known, you can determine the approximate inductance using one of three methods described later: charts, formula, or computer program.

Capacitors C2 through C5 — selected by S1 — allow a broad range of L-C ratios and combinations. The OPEN position of S1 allows you to measure external resonant circuits, or to "trim" an inductor with exactly the value of capacitance needed for resonance at a desired frequency.

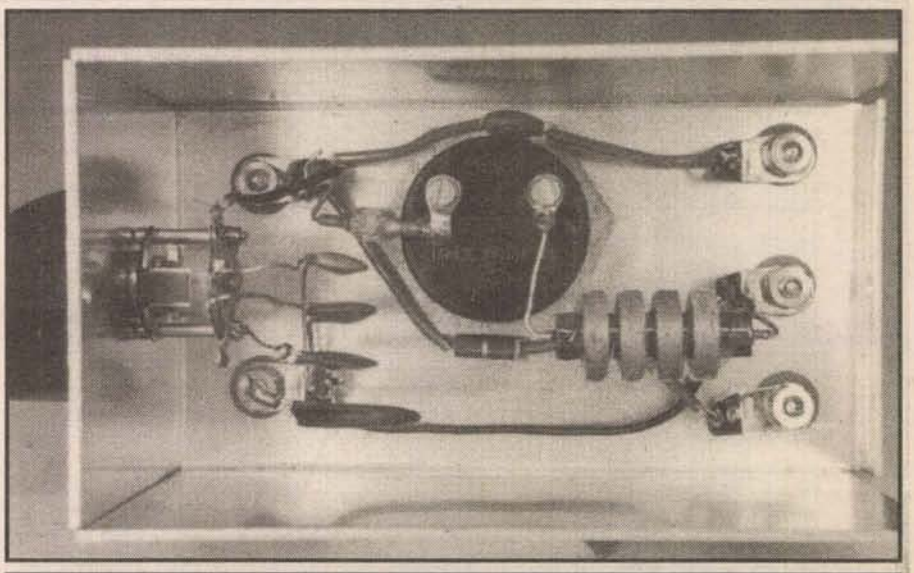
Resistor R1 and capacitor C1 are used to prevent the signal generators from being loaded down by the L-C circuit, which has a very low impedance when not in resonance. Diode D1 must be a germanium diode, since it conducts with a much lower voltage loss than a more common silicon signal diode. RF choke L1 is needed to prevent the meter from acting as a short circuit to the L-C circuit at high-resonant frequencies.

Construction

The author's with-meter unit was built over 30 years ago with parts commonly available at that time. The exact enclosure and meter used then are no longer available, but are not critical. You may have an appropriate small metal or plastic cabinet and sensitive meter in your junk box, or can retrieve them from some other equipment you don't need.

In any case, construction of the unit requires no special techniques. Wiring is not critical, but don't make the leads longer than necessary, and place S1, C2, C3, C4, and C5 near BP4 and BP5. If using a metal cabinet, be sure that all binding posts are insulated from the box; there shouldn't be any electrical connections to the box.

The unknown inductor is connected to the "?" binding posts, and a parallel capacitor selected.



Quick Henry contains few parts, so it is very inexpensive to build.

Circuit Description

Figure 1 shows the schematic of Quick Henry. Assume an audio generator sinewave signal is connected to binding posts BP2 and BP3. The signal passes through isolation resistor R1 and then through the unknown inductance (L) connected across BP4 and BP5. Switch S1 is used to select an appropriate value of capacitance (C2, C3, C4,

The five-position switch used by the author is hard to find, but Radio Shack makes a two-pole six-position switch (see Parts List) that will work fine. You just use one pole and have an extra unused position. Or you can add another "range" by using a 1mF non-polarized capacitor in the sixth position.

The "black box" external-indicator version of Quick Henry, shown in the photos, is built into a

Fuji slide box, designed to hold 36 35mm slides (usually found at photo-finishing stores by just asking). Or look through your old slides and you'll probably find some in these or similar thin plastic boxes that make easily cut cabinets for small electronic projects like this one.

If you intend to use an available external multimeter to detect the resonant condition instead of building the meter into Quick Henry, an analog meter is much preferred to a digital meter. You can observe the analog needle move up scale to a maximum much more easily than interpreting an updating and constantly-changing digital display.

For an external indicator, bring out two wires and clip leads for connection to the external multimeter. These points are marked on the schematic as A and B. Be sure to use red (positive) and black (negative) clips to indicate proper polarity for external connections.

When using an external multimeter to sense resonance instead of the built-in meter arrangement, the multimeter should be set on its lowest DC current or voltage range, observing proper polarity. When using an oscilloscope to sense the resonance voltage increase, set the sweep frequency to see many cycles, and the sensitivity to show the increased amplitude at resonance.

Operation

Most inductors with many turns of wire wound on a ferrite or iron core measure over 1 mH, and can be checked using an audio generator with Quick Henry. Typical air-wound coils are in the microhenry range, so use an RF generator. Never connect both generators to Quick Henry at the same time, as all sorts of spurious signals will result.

Connect the generator "ground" lead to BP2, and the "hot" lead to either BPI (RF) or BP3 (AF). If you are using the external indicator version of Quick Henry, connect the clip leads to the external DC meter or oscilloscope, observing polarity. For more accurate frequency readings than your signal generator readout, you can connect a digital frequency counter directly across the signal generator leads, observing common grounds.

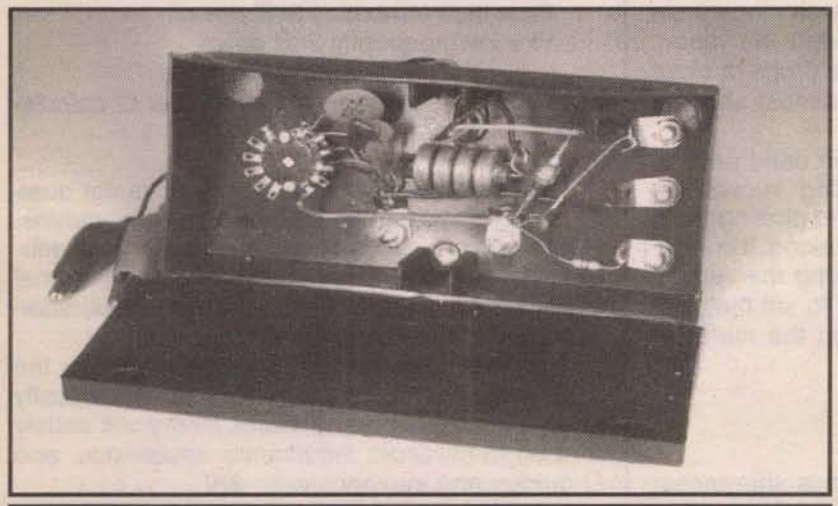
To start with, set SI to the ".OOI" position. Beginning at the low-frequency end of the signal generator, vary the frequency (changing generator frequency bands when necessary) until a clear meter upward deflection is observed. If using an oscilloscope, the amplitude of the display should increase to a peak.

Some minor spurious responses may be seen (especially when using an RF generator and measuring in the low microhenry range), but these can be ignored. Look for a relatively high response as your proper indication of resonance.

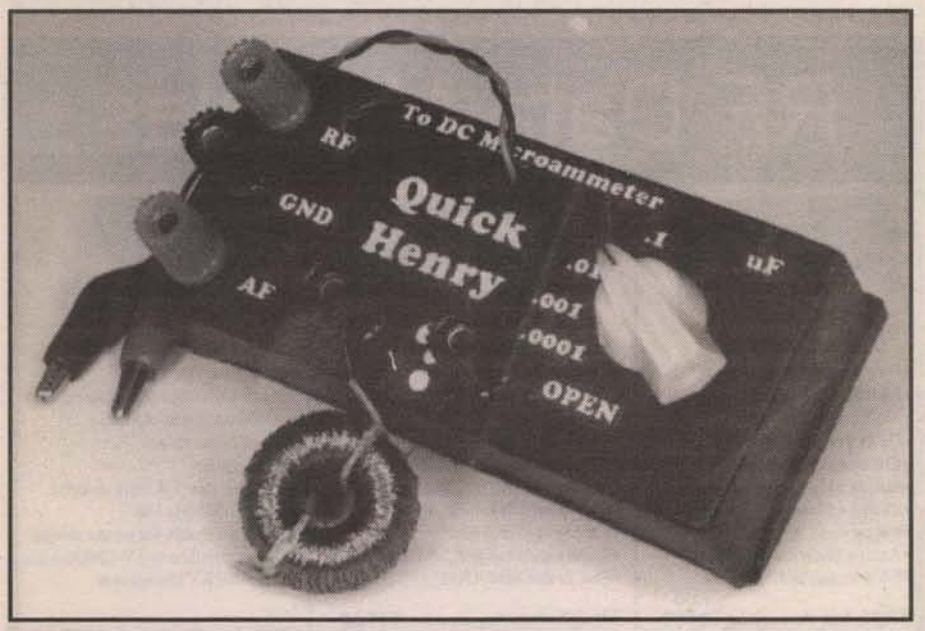
If you don't find any significant response, try switching SI to the next higher value (.01), and sweep the frequencies again. When you do get a response, it will be quite definite, and might "pin" the meter (or scope display). Adjust the generator output for a comfortable peak reading. Most audio generators have enough output to deflect a sensitive meter well beyond full scale, and RF generators will give at least one-half scale under most conditions. The best accuracy will be obtained with the highest value of C that gives a sharp peak meter reading, so re-adjust the position of SI, if necessary.

A broad peak, that is, one which is not too definite in relation to the varied frequency, is "low Q," and may be improved by using a higher value for C (setting SI to a higher value).

Once you have found the best setting for SI (and it really is much easier than it may sound), you can use Figure 2 to determine the inductance of the unknown coil if you're using an audio generator, or Figure 3 if you are using an RF genera-



The meter-less Quick Henry has few parts and can be built into a 35mm slide box for under $10.00.



The unknown inductor is connected to the "?" binding posts and a parallel capacitor is selected with the switch.

```
10 REM * CALCULATE INDUCTANCE *
20 REM * F=RESONANT FREQUENCY WITH PARALLEL CAPACITOR *
30 REM * C=CAPACITOR IN PARALLEL WITH INDUCTOR *
40 REM * L=INDUCTANCE
100 INPUT"RESONANT FREQUENCY IN (1) KILOHERTZ OR (2) MEGAHERTZ";A
110 INPUT"ENTER RESONANT FREQUENCY";F
120 IF A=1 THEN F=F/1000
140 INPUT"ENTER CAPACITANCE IN MICROFARADS";C
200 L=1/(C*(6.28*F)^2)
205 IF A=1 THEN L=L/1000
210 PRINT"THE INDUCTANCE IS";L;
220 IF A=1 THEN PRINT"MILLIHENRIES":END
230 PRINT"MICROHENRIES"
```

LISTING 1: BASIC program to determine inductance when parallel capacitor and resonant frequency are known.

PARTS LIST

RI - 4.7K 1/4 watt resistor (Radio Shack #271-1330)
C1 - 20 or 47 pF ceramic disc capacitor (Radio Shack #272-121)
C2 - .1 uF metal-film capacitor (Radio Shack #272-1053)
C3 - .01 uF metal film capacitor (Radio Shack #272-1051)
C4 - .001 uF ceramic disc capacitor (Radio Shack #272-126)
C5 - .0001 uF (100pF) ceramic disc capacitor (Radio Shack #272-123)
DI - IN34A germanium diode (Radio Shack 276-1123)
SI - Five-position switch (see text. Radio Shack #275-1386)
LI - 2.5 mH RF choke (Ocean State Electronics #6302)
BPI-BP5 - Insulated binding posts (Radio Shack #274-662)
MI - 0-100 microampere meter (see text)
Case - See text
Selector Knob - To fit S1 shaft (Radio Shack #274-424)

SOURCES

- **Your** junk box
- Your local **Radio Shack** store
- **Ocean State Electronics**
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tor. Enter the horizontal scale at the resonant frequency as read on the generator dial or frequency counter and move directly upward until you intersect the line representing the value of capacitance selected by SI. Then move straight to the left and read the value of the unknown inductance on the vertical scale.

Figures 2 and 3 have been plotted showing only the values of capacitance shown in Figure 1. If you desire to use any other values, either internally or connected to the binding posts externally, you can calculate the unknown inductance as follows:

$$L = \frac{1}{C(6.28F)^2}$$

L = inductance in microhenries (uH)
C = capacitance in microfarads (uF)
F = resonant frequency in megahertz (MHz)

When using this formula, be careful about your units; 1000 kilohertz is equal to 1 megahertz, and 1000 microhenries is equal to 1 millihenry. For example, a frequency of 10 kilohertz is .01 megahertz, and an inductance of 10,000 microhenries is 10 millihenries.

A third method to determine the inductance once the resonant frequency is known is to use the simple BASIC computer program shown in LISTING 1. This has worked without modification with Radio Shack TRS-80 BASIC, IBM GWBASIC, QuickBASIC, and QBASIC.

For determining the resonant frequency of, say, an IF transformer, connect one of the windings (an ohmmeter will identify the windings by continuity) to BP4 and BP5, and set SI to OPEN. Using an RF generator, find the frequency that peaks the meter, and read this resonant frequency right off the generator dial. With S1 in the OPEN position, a particular value of capacitor may be placed in parallel with an unknown inductor, and the resonant frequency determined in the same way.

Series resonant circuits can also be measured across BP4 and BP5 by noting a DIP in the meter reading rather than an increase. When not in resonance, the reactance of a series L-C circuit is high and the meter reading is high since most of the input signal is going through the meter. However, the series L-C reactance drops to close to zero at resonance, effectively almost shorting out the meter circuit.

You can actually plot the audio band pass of an R-C or L-C network by taking successive meter readings near resonance and plotting them on graph paper, with frequency along the horizontal axis, and meter reading along the vertical axis. In this case, it is convenient to set the generator output to read full scale on the meter at resonance.

Finding Q

To find the Q (relative bandpass sharpness) of a resonant circuit, you need to determine the frequencies at which the meter reading is approximately 70% of the maximum value. These are the 3dB-down power settings.

Set the peak meter reading to full scale by adjusting the generator output. Now vary the input frequency on both sides of the resonant frequency to the points where the meter reads about .7 of full scale.

Note the frequencies where these meter readings occur and apply the following simple formula:

Q = Fr/(Fh-Fl)

Fr = resonant frequency
Fh = high frequency 3dB down
Fl = low frequency 3dB down

Figure 4 shows an example of a Q calculation.

The accuracy of Quick Henry does not qualify it as a laboratory standard by any means. Numerous errors are cumulative, such as distributed capacitance, stray inductance, the external capacitance of test leads, and the calibration accuracy of the signal generators used.

However, for the home experimenter or the small repair shop or lab, which do not usually need extreme accuracy, Quick Henry will satisfy a need to measure inductance, resonance, and Q quickly and inexpensively. **NV**

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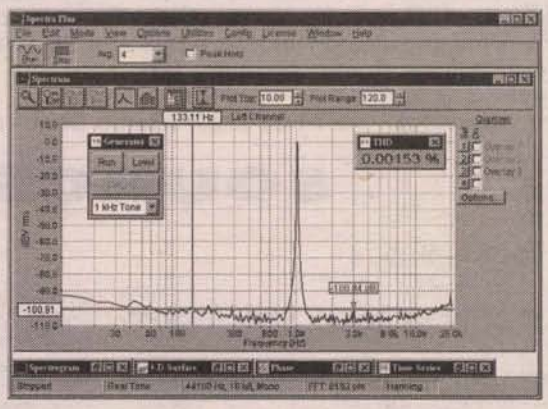

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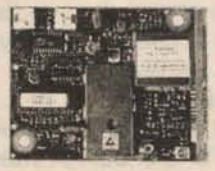

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